United States Patent

Scharfman

[15] **3,660,784**

[45] **May 2, 1972**

[54] **ENERGY ABSORBER AND EVAPORATIVE COOLING SYSTEM**

[72] Inventor: **Howard Scharfman,** Lexington, Mass.

[73] Assignee: **Raytheon Company,** Lexington, Mass.

[22] Filed: **Aug. 28, 1970**

[21] Appl. No.: **67,723**

[52] **U.S. Cl.** ....**333/22 F,** 333/81 A, 333/81 B, 333/98 R

[51] **Int. Cl.** **H01p 1/22,** H01p 1/26

[58] **Field of Search** 333/22, 81; 62/DIG. 12

[56] **References Cited**

UNITED STATES PATENTS

2,262,134	11/1941	Brown	333/22
2,722,616	11/1955	Moses	310/54
3,241,089	3/1966	Treen	333/22
2,850,702	9/1958	White	333/22
2,434,560	1/1948	Gunter	333/22

FOREIGN PATENTS OR APPLICATIONS

1,138,865	2/1957	France	333/22

OTHER PUBLICATIONS

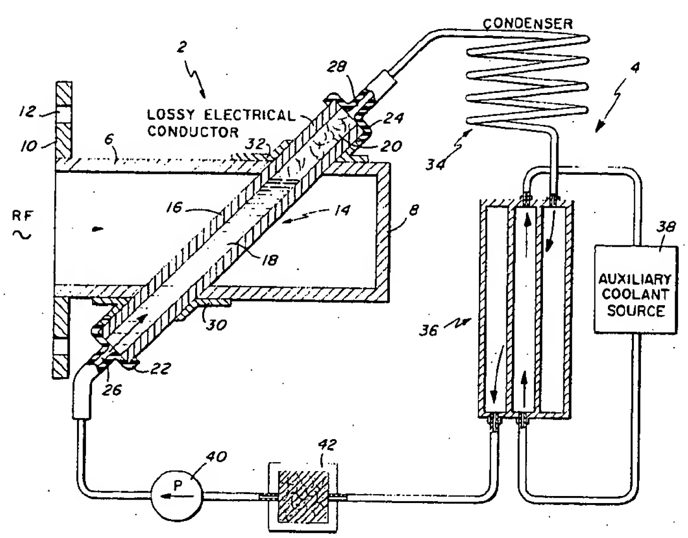
Bogart Bulletin Vol. 1 No. 3 January 1961 Pulisher- Bulletin, Brooklyn, N.Y.; 6 pages.

Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Marvin Nussbaum
Attorney—Harold A. Murphy, Joseph D. Pannone and Edgar O. Rost

[57] **ABSTRACT**

A transmission line termination load or attenuator device is provided with energy absorbing means including a medium for absorption of thermal energy, particularly, in the electromagnetic spectrum. The device is coupled to an evaporative type cooling system to evolve a relatively low pressure, low flow rate means for handling extremely high power levels with a relatively small volume of absorbent. The device utilized in either application has substantially low reflection coefficient characteristics over relatively wide frequency bandwidths and may be in either rectangular or coaxial waveguide configurations.

5 Claims, 6 Drawing Figures



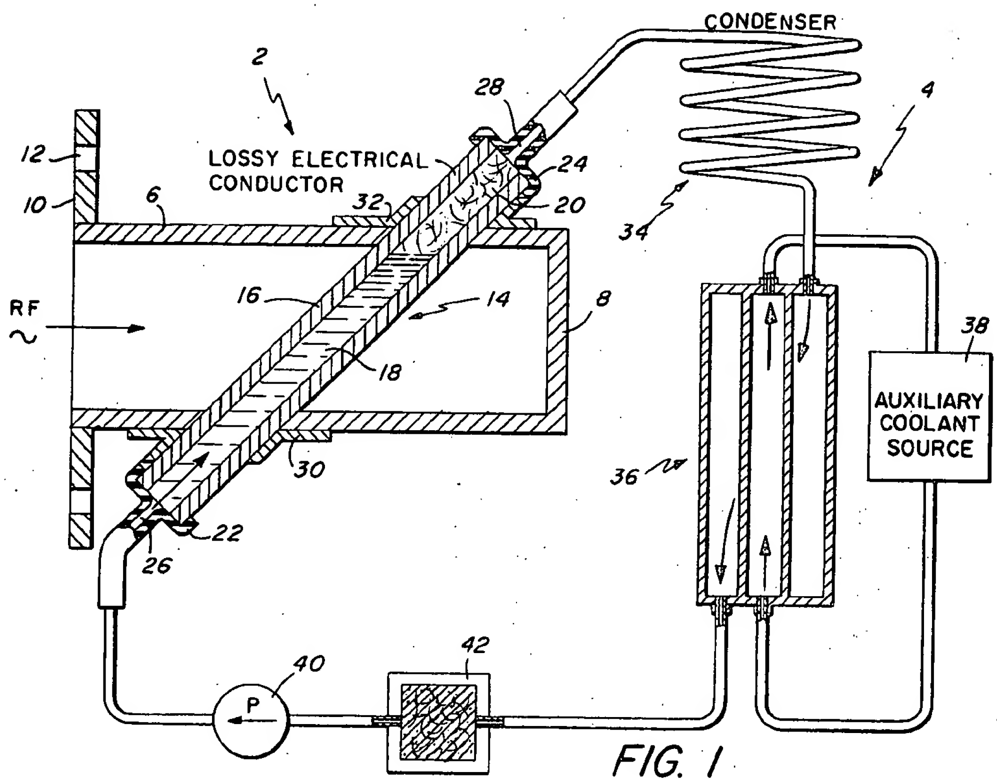


FIG. 1

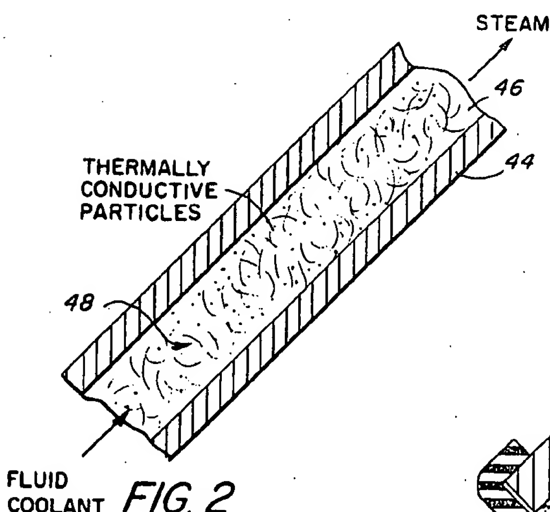


FIG. 2

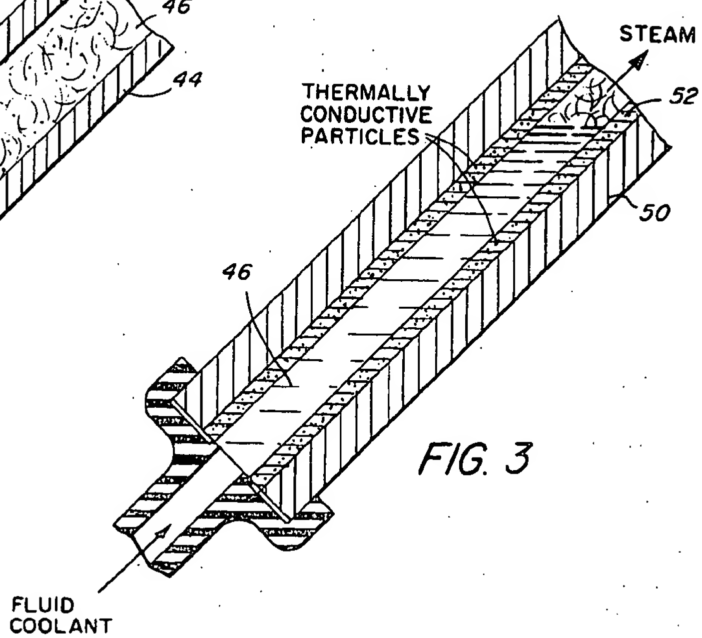


FIG. 3

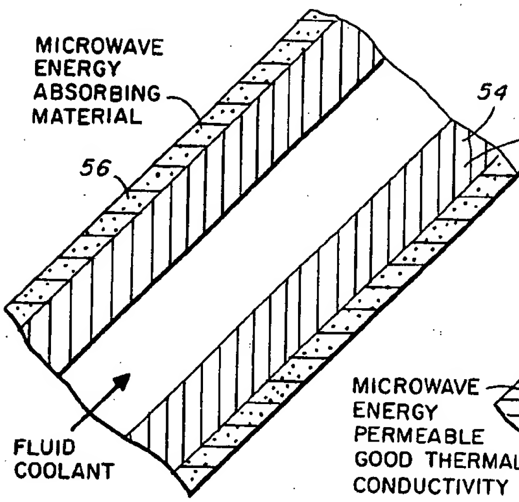


FIG. 4

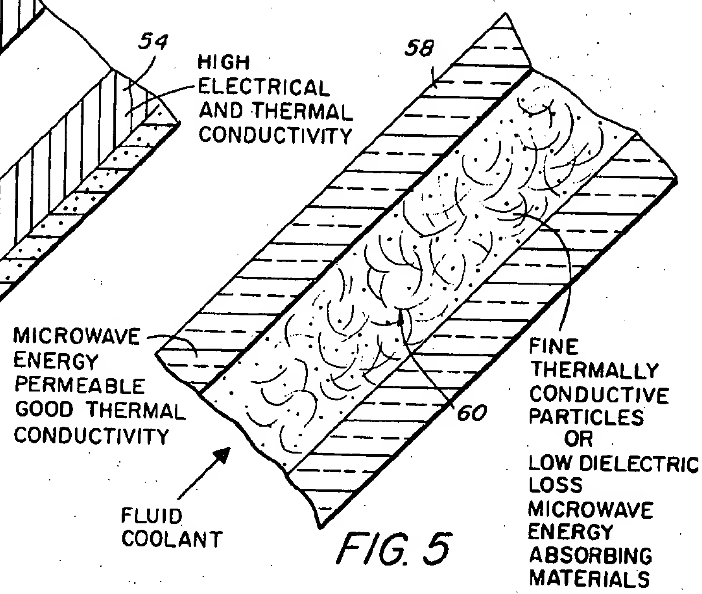


FIG. 5

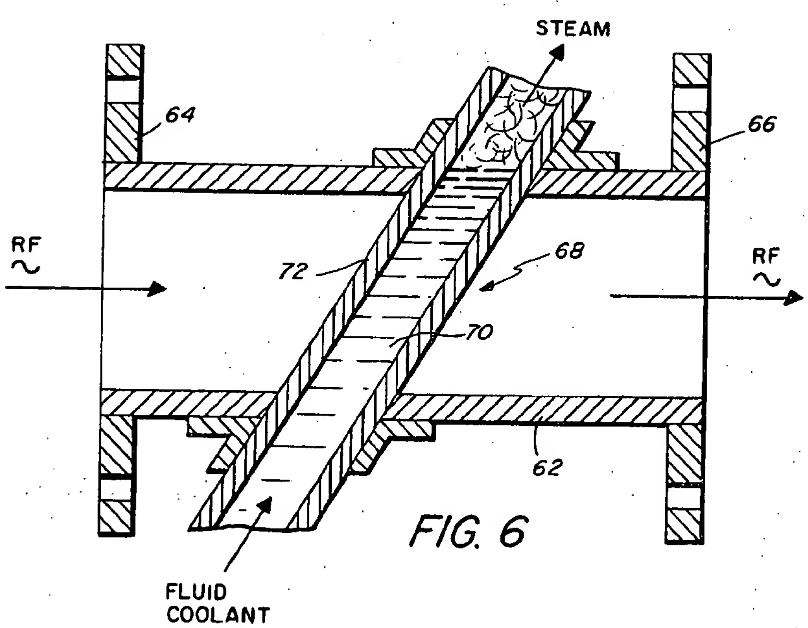


FIG. 6

ENERGY ABSORBER AND EVAPORATIVE COOLING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to electromagnetic energy termination and attenuator devices.

2. Description of the Prior Art

In the prior art the termination of transmission lines, as well as attenuation of energy at intermittent points, particularly, at high power levels, presents a continuing problem in view of the thermal absorption and dissipation requirements. Additionally, it is necessary to match impedances over substantially broad frequency ranges to provide reflectionless electrical characteristics. Prior art devices have evolved having lengths which may run into many feet, at for example, radio frequencies, and combined with the weight of the absorbing materials, such loads have become objectionably bulky and expensive. The high temperatures generated, particularly, with the bulky dry load materials, have also created problems in achieving the desired electrical characteristics of energy transmission systems. Further, such termination devices for use in waveguide, as well as in coaxial transmission lines, have been commonly provided with rather lengthy tapered structures to provide for impedance matching. Such lengthy structures may be disadvantageous when systems are operated under conditions of shock and vibration.

Attenuators for high frequency energy transmission systems are also quite elaborate involving numerous components such as sidewall couplers and phase shifters consuming many square feet of area along with attendant cost and weight problems. The combination of the numerous prior art components in such attenuator structures has also resulted in intolerably high insertion loss values over the frequency bands of interest. In addition, attenuator devices heretofore employed in high power systems are extremely frequency sensitive and hence, unsuitable for broadband frequency applications.

Ideally, energy absorbing termination loads, as well as attenuators, must be capable of handling output power levels which can be as high as many hundreds or thousands of watts of average power, as well as megawatts of peak power, with substantially no reflection of energy and with VSWR ratings, desirably between 1.01 and 1.5. Improved termination, as well as attenuation devices, therefore, of minimal mechanical configuration and reduced insertion loss characteristics over relatively broad frequency bands are essential for more effective utilization, for example, of microwave energy systems.

SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention a transmission line attenuator or termination device is provided with a lossy dielectric absorbing medium extending along a path angulated to the path of the energy. In applications where the device is utilized as a microwave frequency attenuator a section of waveguide is flanged at opposing ends. In the applications for termination of transmission lines an energy absorber is housed within a waveguide section having a flange at only one end.

In one illustrative embodiment a tubular member of a substantially lossy electrical conductivity is filled with particles having a high thermal conductivity and the absorber is angularly disposed within a section of hollow pipe transmission line. As the electromagnetic energy is absorbed by the lossy conductor, the resultant heat is rapidly dissipated by the process of thermal conduction along the tube, as well as throughout the particles of thermally conductive material housed therein. A fluid dielectric coolant such as water or oil is directed through the tubular member by means of a closed loop evaporative cooling system at a relatively low flow rate and pressure. The fluid coolant circulating in the system is rapidly vaporized by the absorbed thermal energy. The resultant vapor is condensed and traverses a heat exchanger mechanism utilizing an auxiliary coolant such as the local domestic water supply. The condensed and cooled fluid medium is filtered and may be recirculated to the energy absorber means or discharged.

Numerous alternative embodiments involving a combination of conductive and lossy energy absorbing materials are disclosed, as well as structures with or without thermally conductive particles dependent on the energy levels to be handled. In all cases the absorbed energy is permitted to heat the contacted surfaces to a temperature in excess of the fluid boiling point to vaporize such fluids circulating through the system and thereby transport exceedingly high thermal energy levels. An outstanding feature of the invention is the capability of absorbing exceedingly high electromagnetic energy including infrared and microwave frequencies utilizing a relatively small volume of the absorbent material. Impedance matching means such as suitable transitions, tapers, steps, stubs, and other matching devices will yield a device capable of achieving the low reflection coefficient characteristics over broad frequency bands.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, as well as the details for the provision of illustrative embodiments, will be readily understood after consideration of the following detailed description and reference to the accompanying drawings, wherein:

FIG. 1 is a cross-sectional view of the energy absorber together with a schematic representation of a coupled evaporative cooling system;

FIG. 2 is partial cross-sectional view of an alternative embodiment of the energy absorber;

FIG. 3 is a partial cross-sectional view of another alternative embodiment of the energy absorber;

FIG. 4 is a partial cross-sectional view of still another alternative embodiment of the energy absorber;

FIG. 5 is a partial cross-sectional view of another alternative embodiment of the invention; and

FIG. 6 is a cross-sectional view of an attenuator embodying the structure of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the FIG. 1 a complete device 2 for microwave frequency energy absorption and thermal dissipation is shown for termination load applications. Such structure is generally found in an arrangement with the termination device mounted in an auxiliary transmission line which is coupled to the main transmission line of a radar system by means of a coupling aperture in a side or common wall. The terminal load devices are also employed in multiported directional coupler transmission line arrangements. The disclosed structure is used for absorbing the incident microwave energy, as well as measuring transmitted power by any of the well known calorimetric techniques utilizing the temperature differential of circulating fluid coolants.

A section of hollow pipe transmission line 6 of either rectangular or coaxial waveguide is enclosed at one end by a terminal conductive end wall 8 which may be fixed or movable in the well known manner, as preferred, for tuning purposes over the frequency bands of interest. The opposing end of waveguide section 6 supports a mounting flange member 10 for coupling the device to adjacent waveguide transmission lines by securing means introduced through coupling apertures 12. The flange members may have conventional choke arrangements and are selected along with the waveguide section in accordance with the standard microwave art for the propagation of electromagnetic energy at a particular range of frequencies of operation. Suitable transformation structures are coupled to the terminal load or incorporated therein such as steps, stubs, or other matching techniques to provide for a low reflection coefficient of the propagated energy. Such impedance matching structures are well known in the art and have not been enumerated or described herein for the sake of

clarity. Further, while the flanged waveguide section has been shown for illustrative purposes, the device of the invention may be mounted in any transmission line arrangement by being incorporated directly in a directional coupler or any conjugate hybrid junction coupler.

The microwave energy absorber 14 in this embodiment comprises a tubular conductor 16 of lossy electrical conductive properties at the electromagnetic wave frequencies of interest, for example, 300 megacycles per second and higher. A dielectric fluid medium 18, such as water or oil, is circulated through conductor 16 at relatively low pressure and flow rates. The absorbed incident microwave energy rapidly heats the conductor until temperatures well in excess of the fluid boiling temperatures are attained. The coolant traversing the walls of conductor 16 reaches its heat evaporization value to become steam as depicted by numeral 20 to transport and dissipate the high thermal energy derived from the microwave power. The ends of conductor 16 are provided with fluid retaining members 22 and 24 to define, respectively, inlet port 26 and outlet port 28 coupled to an evaporative cooling system 4. The energy absorbing element 14 is supported by tubular members 30 and 32 joined to the broad walls of, for example, a rectangular waveguide section 6. It is noted that the absorbing element 14 is inserted within the waveguide section at an inclined angle to its center line to assist in achieving broadband low reflection coefficient electrical characteristics.

The vaporized fluid coolant exits through port 28 and is coupled to a condenser arrangement 34 where the vapor is transformed again into a liquid. A heat exchanger 36 is incorporated in the evaporative system to effectively cool the transformed condensed fluid and lower the the temperature of same through a combination of convection and conduction utilizing an auxiliary coolant source 38 such as, for example, the city water supply. An excellent example of an efficient and compact heat exchanger structure is disclosed in copending application for U.S. Letters Patent, Ser. No. 10,334, filed Feb. 11, 1970, by William H. Hapgood and assigned to the assignee of the present invention. In accordance with this application a heat transfer structure and system is disclosed including a matrix of tubes and spheres bonded together to provide a conduit for a first fluid and a plurality of interconnected paths for a second fluid. The paths are made up of the spaces between the spheres such that the walls of the paths are portions of spherical surfaces. The total path length is made less than 20 times the average radius of curvature of the spherical surfaces and the spacing between adjacent tube elements is of the same order of magnitude as the average length of the paths. A heat exchanger so constructed will effectively transfer substantially all the heat in a heated fluid in average path lengths of 1 inch or less. The fluid medium in the closed loop system is circulated by means of a relatively low pressure pump 40. The condensed cooled fluid may also be filtered by any conventional means 42 and is fed back to the microwave energy absorber through inlet port 26. The utilization of relatively low fluid rates, as well as low circulating pressures, simplifies and reduces the cost of the evaporative cooling system in relation to such components as the ports, valves, joints, and seals. Such pressures also improve the reliability of the system.

Referring now to FIG. 2, an alternative microwave energy absorber is illustrated. A tubular conductor 44 is fabricated of a material having similar lossy electrical characteristics as conductor 16. An exemplary metal such as tungsten, nickel, or nichrome which is substantially lossy at the microwave operating frequencies may be employed. The hollow passageway 46 is substantially filled with particles, such as shavings, spheres, ovoids, cubes, or any other suitable heat exchanging configuration of a highly thermal conductive material such as copper, aluminum, stainless steel, or any of the conductive plastic materials to collectively define a matrix structure 48. The fluid coolant will traverse along the hollow passageway 46 and absorb the heat which is thermally conducted along the walls of the conductor 44, as well as the particles 48 contained inside the absorber. The relatively high temperatures envisaged by the absorption of the microwave power incident upon the walls of the tubular conductor 44, are in excess of the boiling point of the fluid coolant and thereby vaporize such coolant before it exits through outlet port 28. The vaporized coolant is coupled to the evaporative cooling system similar to the arrangement discussed in reference to FIG. 1.

Referring now to FIG. 3, another alternative embodiment of the microwave energy absorber is illustrated. In this embodiment a tubular conductor 50 is coated throughout its inner surfaces by thermally bonded fine thermally conductive particles to define a wall surface 52. The circulating fluid coolant contacting the wall surfaces 52 will be rapidly vaporized as it passes through the passageway by reason of the thermal conduction from the outer wall surface 50 of the tubular conductor. The appropriate selection of materials for conductor 50, as well as the bonded and impregnated particles are selected for the desired power levels to provide the appropriate thermal conduction characteristics to achieve the heat of vaporization level of the circulating coolant.

Referring next to FIG. 4, still another alternative embodiment of the invention is shown for the tubular conductor of the microwave absorbing element. A high electrically, as well as thermally conductive material such as copper or aluminum is utilized for the main tubular body 54. The outer wall surfaces are coated by any suitable techniques such as plating, diffusion or wrapping with a material having a high loss at the microwave frequencies under consideration to provide a contacting surface layer 56. One suggested material to be utilized for the outer energy absorbing medium would be a pyrolytically deposited coating of graphite.

In FIG. 5, still another alternative embodiment is shown. A tubular member 58 is selected from a low loss energy permeable material having fair to good thermal conductivity. Some illustrative materials include glass, ceramic, as well as plastic. Within the conductor member 58 a packing of thermally conductive particles 60 substantially enclose the internal passageway. The fluid coolant will dissipate the microwave energy absorbed through thermal conduction by passing through the matrix of particles and subsequently vaporize such fluid. Alternatively, the packing matrix 60 may comprise particles of a low loss dielectric having a fair to good thermal conductivity. In either embodiment the appropriate flow rate, as well as fluid coolant is selected to optimize the transporting of the absorbed microwave energy by the vaporized coolant.

FIG. 6 illustrates the attenuator application where the amplitude of a wave in a transmission system is controlled with a minimum of distortion. In such applications a waveguide section 62 has secured adjacent opposing ends mounting flanges 64 and 66. In this example, as in the previous embodiments, the microwave absorbing element 68 is disposed angularly with respect to the direction of the propagated waves. The fluid medium 70 contacting the walls of conductor 72 absorbs heat by thermal conduction to vaporize the fluid. An evaporative cooling system is coupled to each end of the tubular conductor. The parameters such as flow rates and materials may be selected to provide the degree of attenuation desired.

There is thus disclosed an efficient electromagnetic energy absorbing means and associated cooling system for handling very high power levels. In those applications where the handling of lower energy levels is contemplated, suitable adjustment such as the omission of packing materials having the high thermal conductivity characteristics in the absorbing means may be practiced similar to the device illustrated in FIG. 1. Many heat dissipation means for the condensed fluid may also be employed within the teachings of the invention. Numerous modifications, alternations and variations, therefore, in structure, as well as the selection of the energy absorbing materials, will readily occur to those skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims. It is intended that the embodiments shown and described herein be considered as illustrative only and not in a limiting sense.

What is claimed is:

1. In combination:

a source of electromagnetic energy;

means for absorbing said energy comprising a hollow member of a lossy electrically conductive material containing a plurality of thermally conductive members;

and means for dissipating the absorbed energy including an evaporative fluid cooling system coupled to said energy absorbing means.

2. An electromagnetic energy attenuator device comprising:

means for propagating said energy along a path;

means for absorbing said energy disposed in said path including a hollow member of a lossy electrically conductive material and a fluid coolant flowing therethrough;

said hollow member containing a plurality of thermally conductive members for vaporizing the fluid coolant to dissipate absorbed heat;

and an evaporative cooling system coupled to said energy-absorbing means.

3. An electromagnetic energy termination device comprising;

means for propagating said energy along a path;

means for terminating said path in an energy reflecting end member;

means for circulating a fluid coolant;

means for absorbing electromagnetic energy including a hollow member of a lossy electrically conductive material containing a plurality of thermally conductive members for converting the absorbed energy by thermal conduction to a level sufficient to vaporize said fluid coolant;

and a closed loop evaporative cooling system coupled to said energy absorbing means.

4. In combination:

a source of electromagnetic energy;

means for absorbing said energy comprising a hollow member having an inner wall surface of a high thermal conductivity material;

and means for dissipating the absorbed energy including an evaporative fluid cooling system coupled to said energy absorbing means.

5. In combination:

a source of electromagnetic energy;

means for absorbing said energy comprising a hollow member of an energy permeable material containing a plurality of thermally conductive members;

and means for dissipating the absorbed energy including an evaporative fluid cooling system coupled to said energy absorbing means.

* * * * *